MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2016/2017

EEL2216 – CONTROL THEORY

(All sections / Groups)

29 MAY 2017
9.00 a.m – 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SIX** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) A particular control system has a second order differential equation given as,

$$\frac{d^2y(t)}{dt^2}+4\frac{dy(t)}{dt}+4y(t)=x(t), \quad x(t)=5u(t).$$

Assume zero initial conditions,

(i) solve the above differential equation. [8 marks]

(ii) calculate the final value of $y(t)$. [2 marks]

(b) Derive, but do not solve the modeling equations in Laplace transform for the rotational car wheel system shown in Figure 1(b). Assume zero initial conditions. [4 marks]

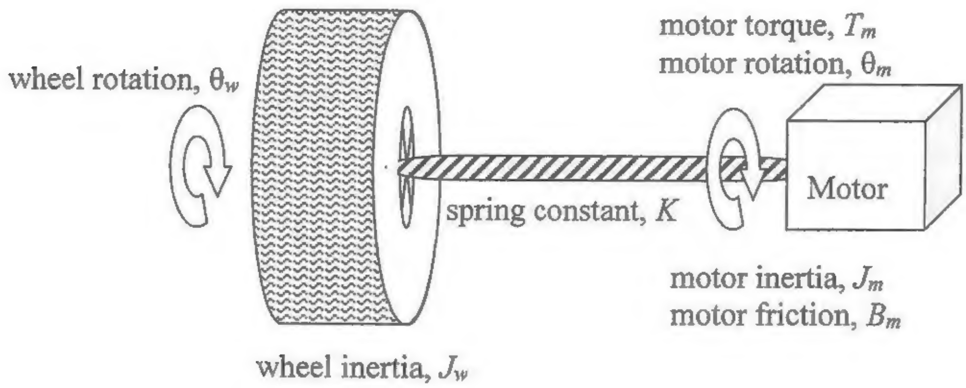

Figure 1(b)

(c) Derive the transfer function $C(s)/R(s)$ for the signal flow graph as shown in Figure 1(c) by using Mason's rule. [11 marks]

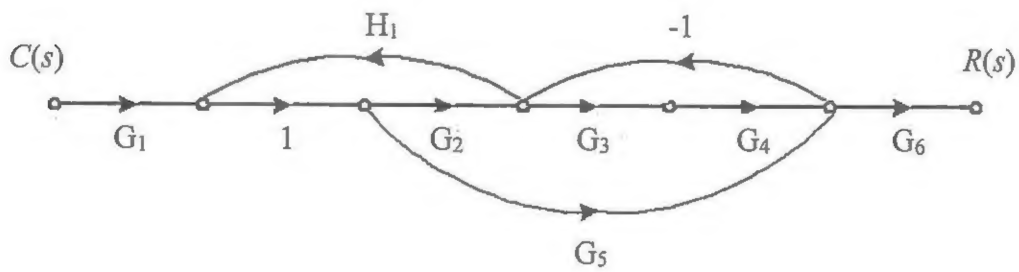

Figure 1(c)

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Question 2

Consider a unity feedback system shown in Figure 2.

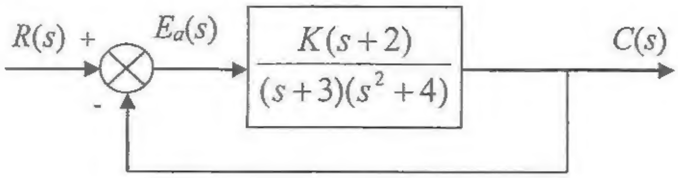

Figure 2

(a) Determine the minimum value of gain K given that the system allows up to 5% steady state error. [4 marks]

(b) Evaluate the range of K for stability. [5 marks]

(c) The loop transfer function of the system is:

$$\frac{K(s+2)}{(s+3)(s^2+4)}$$

(i) List the starting and ending points. [3 marks]

(ii) Find the asymptotes. [4 marks]

(iii) Calculate the angle of departures from the complex poles. [6 marks]

(iv) Based on your answers in parts (c)(i), (ii) and (iii), sketch the root locus. [3 marks]

Question 3

(a) The frequency response of the loop transfer function $G(s)H(s)$ with $H(s)$ is unity, can be plotted in several ways. Name the **THREE (3)** commonly used frequency response analysis methods. [3 marks]

(b) The block diagram in Figure 3(b) shows the transfer function of a plant.

(i) For the given loop transfer function, $G(s)$ derive the logarithmic magnitude and phase angle terms for each basic factors. [15 marks]

(ii) Based on the derived terms in part (b)(i), plot the asymptotes Bode diagram for phase response. [4 marks]

(iii) What is gain crossover frequency? [1 mark]

(iv) Evaluate the stability of the closed loop system if the gain crossover frequency of the plant is 20 rad/sec. [2 marks]

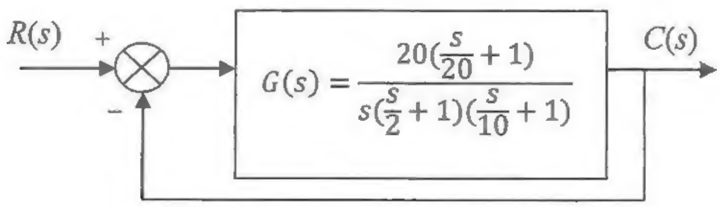

Figure 3(b)

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Question 4

(a) State **ONE (1)** example of an ideal compensator. Draw the respective two op-amp circuit for the given example. [8 marks]

(b) A unity negative feedback control system with a forward path transfer function, $G(s)=\dfrac{K}{s(s+9)(s+12)}$ has a root loci shown in Figure 4(b).

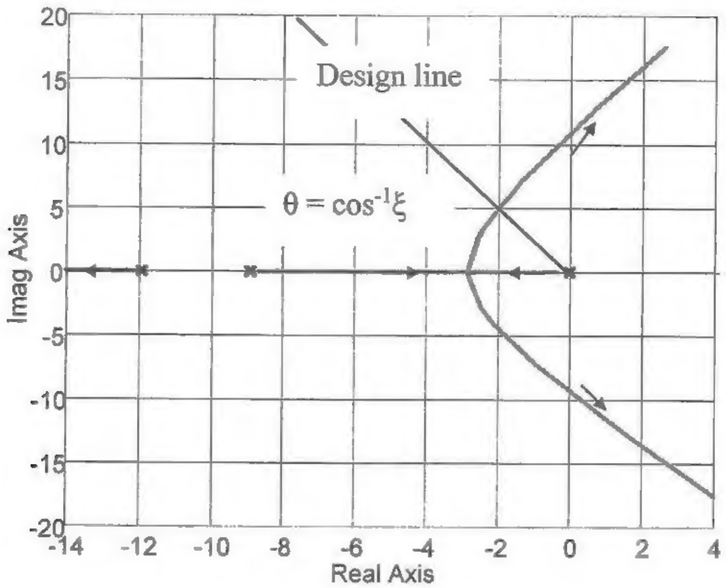

Figure 4(b)

By adding a phase lag compensator with a transfer function, $G_c(s)=\dfrac{(s+z)}{(s+p)}$, the desired velocity constant, $K_{v,comp}$ is equal to 50.

(i) Based on Figure 4(b), what are the desired dominant roots of the compensated system? [2 marks]

(ii) Calculate the desired damping ratio, ξ of the compensated system. [2 marks]

(iii) By using Magnitude Criterion, find the forward path gain, K at the designed point. [5 marks]

(iv) Prove that the desired velocity constant, $K_{v,comp}=\left(\dfrac{z}{p}\right)K_{v,uncomp}$, where $K_{v,uncomp}$ is the uncompensated velocity constant. [3 marks]

(v) Design the phase lag compensator in order to meet the above performance specification. [5 marks]

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Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \; (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \; (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued…

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\ \ (\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper